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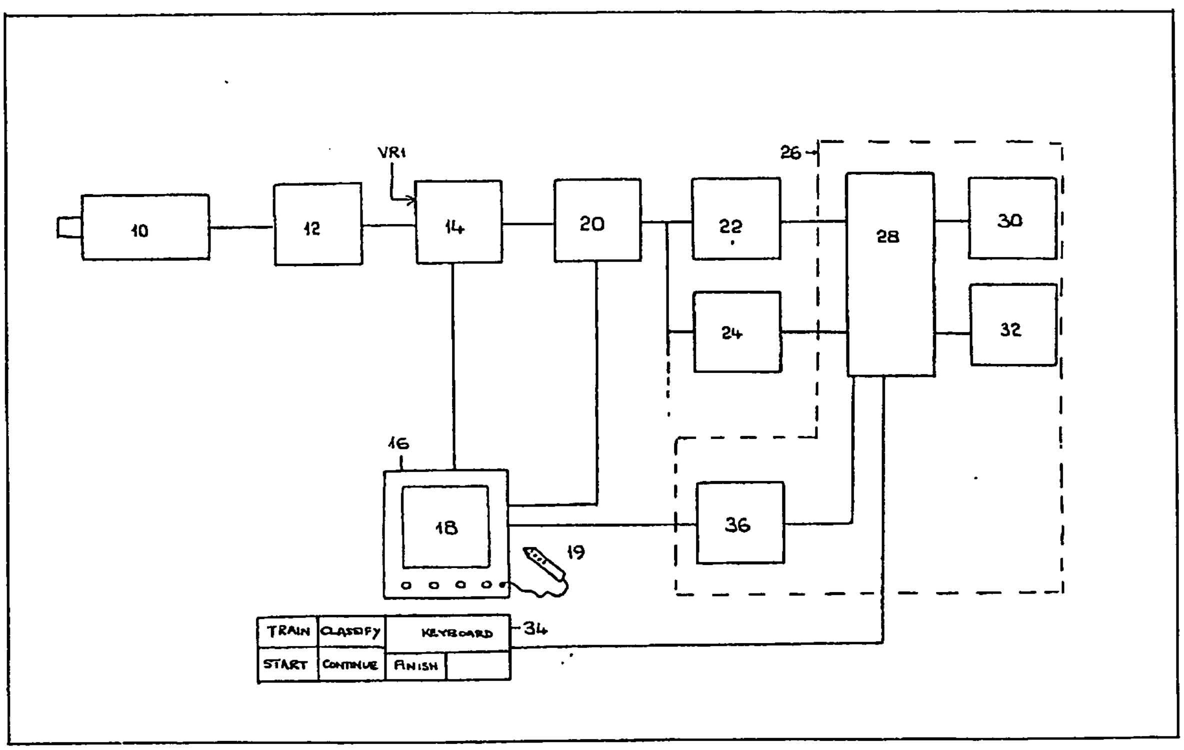
(54) Improvements in and relating to image analysis systems

(57) In a method and apparatus for image analysis of a field of objects processor 28 generates a threshold value for characteristic parameters of the objects, e.g. their areas, dependent on information previously supplied to the apparatus, e.g. by operator interactions (using a light pen 19 or other identifying device) with an image derived from scanner 10 and displayed at 18. Selected objects falling within a given class are indicated on the display and memory 32 stores classifying decisions for the objects together with characteristic parameter values for them. These values are derived from the video signal and calculated by function computers 22, 24, etc.

The threshold value is updated by each classifying decision made by the operator and once a given level of consistency is achieved, the threshold value is frozen and used for classifying future fields of objects by making the same parameter measurements and applying the same threshold criteria to the measured parameter values.

Parameters measurements from a number of selected features may be stored and applied to algorithms in arithmetic unit 30 to reduce spurious parameters for determining object classification. The different algorithm decisions are then compared for consistency and the best algorithm used to determine the classification of objects in future fields.



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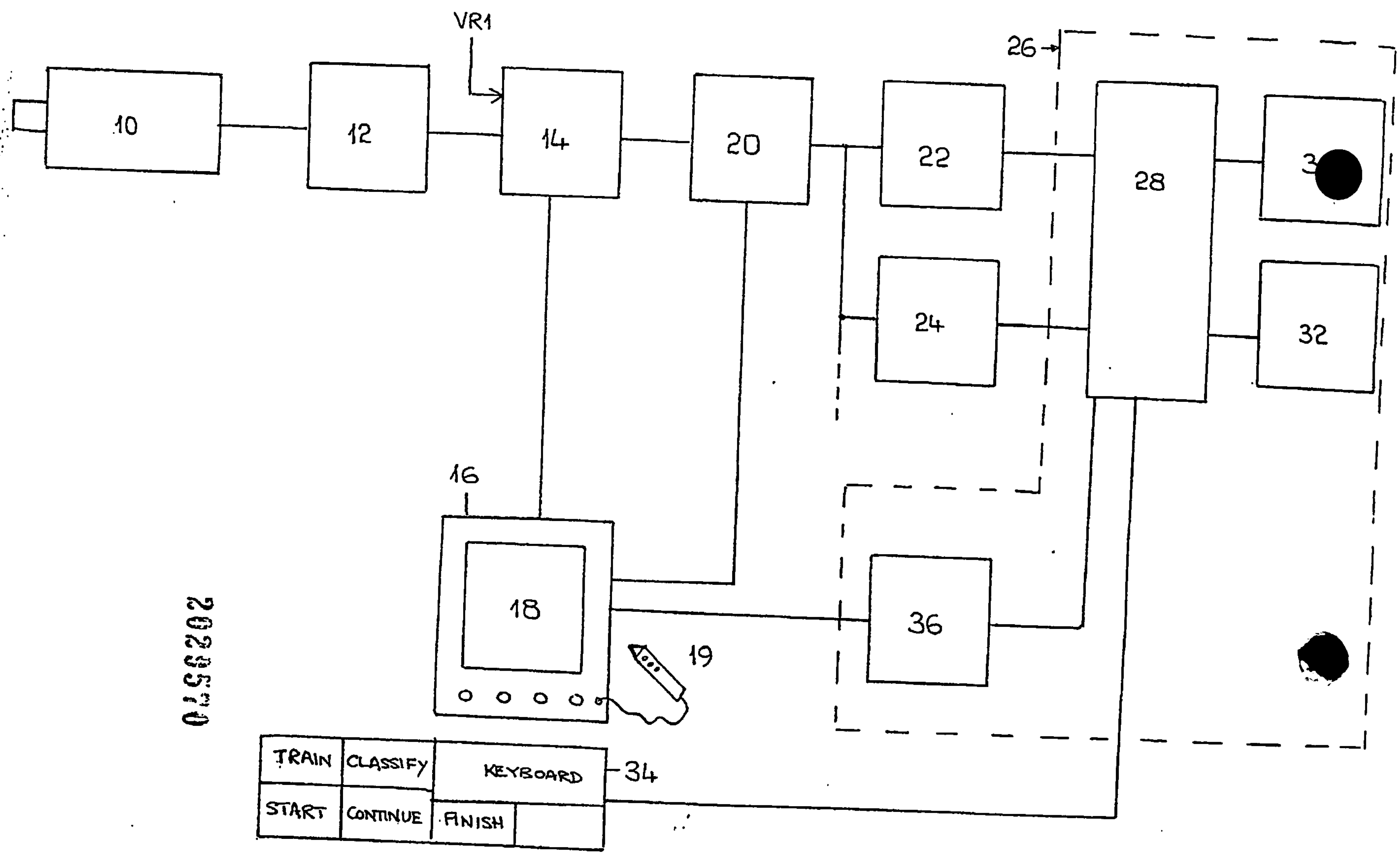
10
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VR1
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20
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CLASSIFY
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START
CONTINUE
FINISH

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SPECIFICATION

Improvements in and relating to image analysis systems

Field of Invention

This invention concerns analysis systems typically but not exclusively image analysis systems. In such a system measurements are made on the information supplied to or derived by the system so as to produce measured valleys of parameters of objects which are under analysis.

Background to the Invention

A typical function for an image analysis system (sometimes referred to as an image analysing computer) is to distinguish between different types of objects. The selection may be made on the measurement of a parameter or parameters by which the objects can be characterized. For example objects may be classified according to size (area) density (light or dark) orientation or shape (typically designated by the expression $\frac{a}{p^2}$ where "a" stands for "area" and "p" stands for the perimeter).

In a known method of operation of an image analysis system, the operator selects a parameter which is believed to be a good basis for distinguishing between different types of objects. This parameter is then measured on a test field of objects and a threshold value for the parameter is chosen which when compared with the measured parameter values for all the objects in the field can be used to divide the objects into two classes, one for which the threshold criterion is satisfied and the other for which the threshold criterion is not satisfied. The result of the classification can be displayed by displaying on a television monitor the field of objects and indicating against each object for which the classification criterion has been satisfied, a small mark or symbol in the display indicating that that object has satisfied the comparison criterion.

There are a number of limitations to the accuracy of this approach:-

(1) The operator tends only to look at a limited number of objects and/or fields containing objects. The threshold value which is set may therefore be biased as a result of the relatively small number of examples which have been used by the operator to check whether the threshold value which has been chosen is correct for all examples of the object which are to be classified.

(2) The operator will not be able to modify the threshold value chosen at the beginning of a long multiple field analysis if during the analysis it becomes clear that the original value of the threshold is not the best that could have been set since the operator will have no way of knowing what effect this change of threshold value will have on the analysis of previous fields.

(3) The operator will usually try only one or two obvious parameters which may be adequate on the first field but do not offer the best general result when all fields to be analysed are considered.

(4) A more complex setting of the threshold value cannot readily be achieved (for example if there is a penalty for getting any one particular classification wrong).

It is an object of the present invention to provide a method of apparatus by which an image analysis system can be instructed by operator interaction to select the best value for a threshold to allow for optimal classification of objects in multiple field analysis.

It is another object of the invention to provide method of apparatus by which an image analysis system may effectively programme itself after initial supervision by an operator so as to not only select the best parameter or set of parameters which are to be measured to achieve any given classification but also the optimal values for the threshold criterion to be applied.

The Invention

According to one aspect of the present invention a method of setting the value of a classifying threshold in an image analysis system comprises the steps of:-

(1) scanning a field containing features to be analysed, to obtain a video signal of the features,

(2) displaying the video signal on a TV monitor,

(3) selecting a specimen feature from the display,

(4) causing the analyser to make measurements on signals obtained from the video signal, to produce a value signal of a parameter of the specimen feature,

(5) the analyser generating from the value signal a classifying threshold for comparison with value signals obtained by scanning other features,

(6) the forming of said comparison,

(7) generating and identifying signal for each comparison for which the classifying threshold criterion is satisfied, and

(8) displaying the identification signal for each feature in the display which satisfies the said criterion, to allow a visual check to be made on the accuracy of the setting of the classifying threshold by the analyser.

According to another aspect of the invention, apparatus for performing the above method comprises:-

(1) means for scanning a field containing features (or an image of such a field) and producing from the scanning a video signal corresponding to the features,

(2) TV monitor means for displaying the video signal,

(3) manually operable means for selecting a specimen feature from the display,

(4) circuit means within the analyser to make measurements on signals obtained from the video signal to produce a value signal of a parameter of the specimen feature,

(5) further circuit means for generating from the value signal a classifying threshold for comparison with value signals obtained by scanning other features,

(6) comparison means for performing said comparison,

(7) signal generating circuit means for generating an identifying signal for each comparison for

which the classifying threshold criterion is satisfied, and

(8) means for causing the identifying signals to produce visible identification marks in the said TV display for each feature in the display which satisfies the said threshold criterion to allow a visual check to be made on the accuracy of the automatic setting of the classifying threshold.

According to a related aspect of the invention, step 8 of the aforementioned method comprises:-

(1) visually checking the displayed identifying signal with the display of the feature to which it relates,

(2) removing or changing the identifying signal for a feature which has been incorrectly classified by the analyser, and

(3) modifying the value of the classifying threshold to take account of the parameter value of the incorrectly identified feature.

It will be seen that by adopting such a method, the setting of a classifying threshold will be automatically adjusted to take account of the spread of the parameter values of specimen features so that the optimal value for the classifying threshold can be obtained without the operator being required to do other than recognise when the analyser has performed an incorrect classification of a displayed feature.

Apparatus for performing this overall method comprises, in addition to the aforementioned apparatus,

(1) means for selecting a specific identifying signal display in the television monitor display,

(2) means for eliminating the video signal content producing the identifying mark in the television monitor display, and

(3) circuit means for adjusting the value of the classifying threshold in response to an elimination of video signal content producing an identifying mark in the display, to take account of the parameter value of the incorrectly classified feature.

In a preferred method according to the invention, the parameter value signals for a feature which is identified as being incorrectly classified, together with signal information indicating the correct classification for the feature, are stored in a store and an average value for the classifying threshold is obtained by combining with (or eliminating from) the parameter values determining the classifying threshold, the stored parameter values from the feature shown to be incorrectly classified, so as to produce a new value for the classifying threshold which takes account of the additional or reduced parameter values to be used in determining the classifying threshold.

Apparatus for performing the preferred method comprises:-

(1) a signal store adapted to store the parameter value signals for a feature identified as being incorrectly classified together with signal information indicating the correct classification for the feature,

(2) circuit means for producing an average value of two signals supplied thereto,

(3) a second store for storing the classifying threshold,

(4) means for addressing the two stores and supplying signals therefrom to the averaging circuikt to produce a new classifying threshold value, and

(4) circuit means for replacing the signal in the second store with the new classifying threshold.

In a further preferred method, the comparison step for a feature identified as being incorrectly identified is conveniently performed a second time after the new classifying threshold has been determined by the averaging circuit but the subsequent classification of the previously incorrectly classified feature is taken to be correct even if the subsequent comparison after correction of the classifying threshold value still indicates an incorrect classification for the feature.

This process may result in a further apparent mis-classification of a feature where its contribution to the value of the classification threshold is too small to alter the classification threshold value sufficiently to include that feature within the classification.

The method of the invention may include the further step of recording the number of successful classifications of features in each of a succession of fields to allow the determination of the level of accuracy to which the analyser can perform future classifications. When the sufficiently high level of accuracy has been achieved, the analyser can be left to perform future classifications of similar fields unsupervised.

According to a further aspect of the invention, a method of analysis using an image analyser comprises the steps of:-

(1) scanning a field containing features from *n* different groups,

(2) entering information into the analyser to indicate the number *n* of groups into which the features will fall if classified correctly,

(3) making measurements on signals obtained from the scanning of the features to produce value signals therefrom of different parameters of the features,

(4) performing a series of comparisons of the value signals with a plurality of threshold values to form *n* groupings of the signals,

(5) noting and storing the values of the thresholds which result in *n* groupings,

(6) scanning future fields containing similar features belonging to the same *n* groups,

(7) comparing value signals from the scanning of the subsequent fields with the stored threshold values to classify the features in the said subsequent fields,

(8) displaying each field whilst it is being scanned, and

(9) generating identifying signals for producing identifying marks in the display for indicating the particular classification of each of the features in the display resulting from the said comparisons.

Preferably the series of comparisons using thresholds for forming the *n* groupings may be modified as a reslt of visual inspection of the identifying marks in the display, to allow operator interaction, the modification being effected either by

the operator directly or by the analyser in response to information inserted by the operator.

According to another aspect of the invention an analysis system for classifying a plurality of detected features in a field of view comprises:-

(1) means for performing measurements on information arising from scanning a field containing the features so as to obtain information signals corresponding to the numerical value of a parameter of each detected feature,

(2) means for identifying selected ones of the features as falling within a class,

(3) means for deriving a classifying threshold from the information signals relating to the measured parameter of the identified features,

(4) means for storing a signal corresponding to the classifying threshold value, and

(5) means for comparing during the scanning of the field (or subsequent fields) the measured value of the same parameter for other features with the classifying threshold or a signal derived therefrom and generating identifying signals from said comparison to produce classifying indication marks in the display for indicating those features in the display which fall within each of the said *n* classes.

In such a system means may be provided for producing statistical information signals from the measurements, which means may be capable of being switched into or out of operation by the operator and means may be provided for clearing the memory within the system of some or all of the statistical information signals previously stored therein so that statistical information signals relating to a fresh type of field can be derived by the system and stored in the memory. Such a system is said to have two modes of operation, i.e.

(a) a learning mode, and

(b) a classifying mode.

In mode (a) the system is set to perform measurements on different parameters of each detected feature in the field and the operator indicates by means of a keyboard or some other form of indicating device which of *n* groups the feature most closely approximates to. This information is stored in further memory means so as to be related by the system to the statistical information obtained from the measurements made on that feature as well as the other features in the field.

In mode (b) the statistical information stored in the memory is used to determine the threshold values or numerical values of constants etc. with which subsequently obtained information relating to measured feature parameter values is compared, so that subsequently investigated features can be classified as falling in one of the *n* different groups.

In a further development of the invention, means may be provided for determining which of *m* sets of statistical information obtained during the learning mode of operation are the dominant statistical information signals relating to the particular classification problem in hand and the means for comparing subsequently arising measured value signals or information signals derived therefrom with the comparison threshold derived from the statistical information signals, being adapted to discriminate between those statistical information signals which are deemed to be dominant and those which are not, so that comparison criteria based on the dominant statistical information signals only, are compared with the subsequently obtained information signals relating to the features under analysis.

This last mentioned system can be said to have three modes of operation, i.e.

(a) a teaching mode

(b) a selection mode in which the dominant statistical information signals are selected and retained and the others either disgarded or stored but not referred to, and

(c) a classifying mode in which the information signals arising from scanning features is compared with comparison criteria determined by the dominant statistical information signals for the purpose of obtaining classifying signals for classifying detected features as falling into one of *n* groups.

In a third embodiment of the invention there is provided means for indicating the number of classes or groups of features which are present, means for accumulating and storing measured parameter values for each of the features and means for determining from the parameter measurements and the number of classes or groups which are present, those parameter measurements which define that number of groups, means for deriving statistical information from the stored signals corresponding to the parameter measurements which have been stored for the features in the field and comparing the measured values of the selected parameters with the statistical information, and obtaining therefrom information signals relating to each of the features by which a classification can be performed, to determine into which of the groups or classes each feature should be classified.

It will be seen that an operator in charge of this last mentioned embodiment of the invention need only have a basic minimum of information and knowledge about the particular field under analysis.

The invention will now be described by way of example with reference to the accompanying drawing which is a block circuit diagram of an image analysing system based on the Quantimet (Registered Trade Mark) 720 Image Analyser.

General description of System

The system shown in the drawing consists of a Quantimet (Registered Trade mark) 720 Image Analyser which is made up of a scanner 10 adapted to produce a video signal by scanning a field containing features, video processing circuits 12 and an amplitude comparison or detector circuit 14 to which the video signal is applied. In addition one or more reference voltages such as VR1 are supplied to the detector 14 for comparison with the video signal. The output from the detector circuit 14 comprises a binary signal having constant amplitude pulses of variable duration. The constant amplitude pulses may be gated by an electronic switch to produce high frequency pulses for counting, the number of pulses appearing in place of each constant amplitude pulse corresponding to the duration of the pulse which they replace.

The output signals from the detector 14 are supplied to a display unit 16 which includes a CRT and in addition to the original video signal (as processed by the circuits 12) the output signal from the detector 14 both before and/or after gating by the electronic switch is/are available for display either separately or in a superimposed manner or in sequence one after the other, on the display screen shown at 18.

In addition the output signals from the detector circuit 14 are supplied to a standard computer module type MS3 of the Quantimet (Registered Trade Mark) Image Analysing Computer range. The standard computer 20 is adapted to associate the signals in the output of the detector circuit 14 so that trains of electrical pulses can be assembled in a memory circuit in real time each train defining an area within the scanned field which corresponds to a feature which has been detected according to the detection criterion applied by the detector circuit 14. The standard computer 20 produces a single output signal when the train of pulses relating to any particular feature has terminated and the computer operates in such a way so that the point during the frame scan to which this single output signal is produced for any particular feature is defined at least in part by the geometry of the feature and is essentially fixed in time and space in the scanning.

The trains of signal pulses defining the detected areas and the single output signals are supplied to the display unit 16 and if required can be arranged to produce visible outlines or areas or marks as the case may be in the display. Thus the train of pulses relating to a detected feature will produce an area which can be brighter or darker by selection, than the display of the feature to which the pulses relate and the single output signal for the detected feature concerned can be arranged to produce a small bright or dark mark in the display at the bottom right hand corner of the region in the display corresponding to the feature.

The trains of pulses corresponding to the various detected features in a field are supplied to each of a number of separate function computers, 22, 24, etc. Each function computer is of the type described in Image Analysing Computers Technical Data Sheet 7223/2, and comprises one of the function computer modules within the Quantimet Image Analysing Computer range. Each function computer module is adapted to receive trains of pulses of the type supplied by a standard computer 20, each train relating to a single feature, and to compute from each such train of signals for a feature, either the integrated volume, or the area, or the perimeter, or the vertical or horizontal projection, or the horizontal or vertical feret diameter, of the feature.

By providing one function computer 22, 24, etc. for each of the parameters in respect of which measurements are required, so all the measured parameter values will be made available for any one of the features or objects in the field at (or after a short fixed time interval from) the unique and reproducible point during the frame scan determined by the single output signal for that feature produced by the standard computer circuit 20.

In the embodiment shown, only two function computers are provided namely 22 and 24. However it is to be understood the invention is not limited to the use of two function computers and any number of function computers may be employed in practice.

Outputs from the two function computers 22 and 24 are supplied to a further module which represents the heart of the invention and comprises a series of computing circuits and control circuits for operating on the information signals supplied by the function computers 22 and 24. The new module will be referred to as a "learn module" and is generally designated 26.

Within the module 26 is a logic control unit 28 which is supplied with signals from the two function computers 22 and 24. Outputs from the control unit 28 provide signals for an arithmetic unit 30 and a memory 32.

Additional input signals for the control unit 28 are obtained from a control keyboard 34 and additional output signals from the control unit 28 operate on a text generator circuit 36 for generating alpha numeric characters and other symbols in the display of the unit 16.

In basic modes of operation, the operator has to be able to interact with the system and select trains of pulses relating to individual features in the display of features. To this end a light pen 19 is provided. This pen can be pointed by the operator at the display on the screen of the CRT in the display unit 16 and includes a photoreceptor device which responds to an illuminated region of the screen which is brighter than the surrounding area of the screen. An electrical mark a pulse can therefore be obtained from the photo-receptor device by appropriate amplification as the minute spot of light forming the display in the CRT scans across the area to which the light pen photo-receptor is pointed, provided the video signal supplied to the CRT causes the spot of light at that instant to have an appropriate brightness.

Such devices are well known and a light pen system is available for use with and as an integral part of Quantimet Image Analysing Systems as supplied by the Applicants.

The marker signal obtainable from the light pen circuit can be used to generate a series of gating pulses which wil release the train of electrical pulses relating to a feature by pointing the light pen in an appropriate manner at the feature for which the train of pulses is required. In this way the train of pulses which appear in the output of the detector 14 for any detected feature which has been earmarked by the light pen can be arranged to appear during each frame scan that the light pen is pointed at the feature to the exclusion of all other detector output signals arising during the scanning.

The train of pulses so selected by the light pen will be referred to as isolated train of pulses.

The overall system consists of part of the standard Quantimet (Registered Trade Mark) 720 Image Analysing Computer which has the facility for:-

(a) "learning" the characteristics of a class of objects under instruction from an operator, and

(b) subsequently classifying objects presented to the image analysing computer according to the

characteristics learned during mode (a). The new facilities of this are provided by the learning module 26.

The operation of each of the separate parts of the learning module 26 can be described as follows:-

(a) the control unit 28 sequences through the required actions and processes the input data,

(b) the arithmetic unit 30 performs calculations on data supplied to it by the control unit 28 and provides answers which are again processed by the logic control unit 28,

(c) the memory unit 32 stores the parameters of a classification algorithm as they are calculated by the arithmetic unit operating in conjunction with the control unit 28.

(d) the text generator 36 serves to display the information on the CRT screen 18 of the display unit 16 to inform and instruct the operator. Typically the information generated by the text generator 36 is superimposed on any display visible on the CRT screen.

(e) the keyboard 34 which includes an alpha-numeric keyboard and five special function keys, allows the operator to set up the control unit 28 so as to operate in a particular way and also allows the operator to insert information into the instrument.

Basically the system responds to a sequence of questions presented in order by the learn module 26. One set of questions constitutes the training mode of operation and the other set of questions the classifying mode of operation.

Basic training mode.

In the basic training mode the following operations are performed:-

(a) The operator indicates a few typical objects in each class to the instrument. This is most simply achieved by pointing the light pen 19 at the objects in turn. The parameter values from the function computers 22 and 24 for each indicated object are stored in memory 32 and a threshold for classifying future objects is obtained from stored values,

Alternatively the operator may set an initial threshold within the control unit 28 which serves to separate the objects of one class from the other objects in the displayed field by selecting one or other of the parameters measured by the function computers 22 and 24. Either method will provide the instrument with "initial information",

(b) The instrument is adjusted so as to perform measurements via the appropriate function computer 22 or 24 on the selected parameter for all the objects in the field, and the results are stored in memory 32,

(c) on the basis of the initial information the control unit circuitry 28 automatically selects a threshold value for comparison with the parameter value signals arising during the scanning in this latest mode of operation and electrical signals are generated in response to each such comparison and an electrical signal is produced from each such comparison for initiating and producing an indicating mark in the display adjacent or superimposed on each detected feature for which the comparison criterion dictated by the automatically set threshold is satisfied,

(d) the operator can now see the result of the classification undertaken by the apparatus. The features which the instrument has classified as satisfying the threshold criterion will each have associated therewith an indicator mark. The operator can therefore now interact with the instrument and check the classification using his own knowledge and experience. If the automatically set threshold is not correct of if the wrong parameter is being measured in an attempt to obtain the classification, this will become evident when the operator inspects the display. Interaction as before is achieved by using the light pen 19 and in this current mode of operation, the light pen 19 is pointed at any detecfed features in the display which have apparently been incorrectly classified. Thus the light pen includes or is associated with switches by which an electrical marker signal can be generated for any feature which has not been classified and should have been, and the marker signal generated by an incorrect classification of another feature can be removed from the display. Removal of the marker signal is also arranged to erase the output signal corresponding to the measured parameter for that detected feature from the section of the memory containing parameter values of previously classified features into another part of the memory containing signals relating to unclassified features and vice versa,

(e) after the operator has corrected the classification of all incorrectly classified displayed features, the instrument is instructed to recalculate the threshold based on the new information contained in the memory. The correct identification of each detected feature is stored in another region of the memory 32 and after revision of the threshold value, electrical signals corresponding to a revised classification of the detected features are obtained and stored in another region of the memory 32 and this new classification is displayed with appropriate marks in the CRT display. (It is to be noted that as a result of the recalculation of the threshold value, the reclassification of the detected features may correspond to the correct classification as dictated by the operator but it may not necessarily be the case since, the system may be attempting to classify features using either the wrong parameter or an insufficient number of parameters in order to guarantee correct identification of each detected feature.)

(f) A further region of the memory 32 is provided for storing a large number of parameter value signals for different features and this further region of the memory is divided into two compartments into which the parameter signals are located according to the classification achieved by the threshold value obtaining when those objects were scanned. Since the memory also includes in another part, the correct classification of the same parameter value signals, the arithmetic unit 30 can be adapted to produce a percentage indication of the accuracy of the classification using the previously set threshold value. This percentage accuracy value can be displayed conveniently using alpha-numeric characters in the display on the television screen 18. After checking the current percentage accuracy, the para-

meter value signal previously classified by the automatically set threshold are reclassified according to the updated threshold value and the operator can check to see whether the percentage accuracy on the screen 18 has been improved or worsened.

The process can be continued to the capacity of the memory which will be the only limiting factor on the number of objects which can be measured and for which parameter value signals can be stored and used to generate and update a threshold value for subsequent classification of objects presented to the instrument.

(g) Where the memory capacity is sufficient, a number of different fields of view can be selected and operations as set out in steps (c) to (f) above can be repeated. In this way the automatic threshold which is to be used for classification purposes can be set from information arising from the scanning of a succession of different fields of view each containing objects which are to be classified. Again provided the memory capacity is sufficient, after a number of such fields have been measured it will be found that the percentage accuracy indication in the display will have reached a limiting value. Provided this is sufficiently high the instrument can be switched to an automatic mode of operation in which the threshold value is maintained constant and classification of future fields supplied to the instrument will be in accordance with the latest value of the threshold. Provided the content of the field is consistent and assuming the equipment continues to operate correctly, the instrument will perform the classification on the subsequent field of objects to the same level of percentage accuracy as indicated in the display.

(h) In the alternative, the operator may decide that the percentage accuracy achieved during the learning procedure is not high enough and either can select an alternative parameter to be measured by the function computers in an attempt to find a better method of classifying the objects or can decide to perform an overall classification of a series of fields with an override facility on each field thereby allowing the operator to correct any misclassified features in each field as it is displayed. Obviously the procedure will be slower than if the instrumsent were capable of being left in an automatic mode of operation for the overall classification but it will be still faster and more accurate than a manual method applied to each field in turn requiring each of the features in the field to be separately classified, for example using the light pen.

It will be appreciated that in a method as previously described the instrument will have accumumlated a much larger data base on which it can make an unbiased decision on the precise setting for a threshold than would have been available to the operator. The operator should have to make less and less intervention as the measurements proceed and the instrument accuracy improves assuming that the correct parameter has been chosen for measurement purposes.

The important point is that although any one field may not be 100% correct the instrument will select a threshold which will give the best average result over a large number of fields. A human operator would naturally bias a threshold to get a single field correct and in a multiple field analysis will not always yield the best statistical result.

Although the method of operation has been described so far in relation to making measurements of only one parameter of the features under analysis, it will be appreciated that two or more parameters may be measured for each feature and results compared with two separately and independently set thresholds so as to allow for a more concise classification of one class of features from others. Thus for example not only the area but also the density (optical density) of the features measured by two function computers and features classified according to whether or not they exceed a given area and a given optical density. Features will then only be classified into the selected group when their measured parameters of area and density satisfy both of the threshold criteria.

It is also recognised that allowing purely automatic parameter selection without any further modification does not allow the threshold setting circuits within the instrument to benefit from an operator's knowledge of the problem in hand. The method may therefore further include the step of feeding additional information into the memory 32 to allow other factors to be taken into account or used to modify the results on a field by field basis to improve the accuracy of the analysis. Thus for example two parameter modes (isotropic and anisotropic) may be selected. These two modes are used to indicate that the operator is specifically interested in the orientation of the objects or that it is orientation independent parameters that are required. The instrument will then only respond to parameters according to whether they are orientation dependent or otherwise.

In a similar manner the information fed into the instrument by the operator may introduce a bias. For example in some forms of analysis there may be a cost or other penalty attached to a misclassification. Such information fed into the instrument would bias the decision making circuits so that misclassification of one type will never occur even at the expense of overall accuracy of classification of objects.

So far only a relatively simple mode of operation has been described in which the threshold value is set and corrected according to operator interaction with the equipment but in which the operator selects the parameter or parameters in advance and therefore requires to know in advance how the features in the field are to be classified. In some cases such knowledge is either not available or if only available to a skilled operator and in order to allow analysis equipment of the type described to be used by a relatively unskilled operator further refinements can be provided and a further method of operation will now be described again with reference to the circuit diagram shown in the drawing. The mode of operation now to be described allows an instrument having appropriate memory and computing capacity to not only select the correct value for a threshold so terminate the training procedure or present another field for the training programme to continue. The

as to perform an appropriate classification but also to select the parameter or parameters to be measured so as to obtain the classification which is required.

Operation can be described under two headings namely, Training Mode (previously referred to as learning) and Classifying Mode.

Training mode.

1. The start control on the keyboard 34 is pressed. This resets all circuits and produces in the display via the text generator 36 an instruction "set up detector and other image analysis functions".

2. The operator adjusts VR1 and the instrument stores in the memory 32 information which will allow the instrument to reset the threshold VR1.

3. The text generator 36 generates another question "train or classify" and the operator selects the appropriate function on keyboard 34.

4. If a training mode is indicated the control unit 28 causes 36 to generate a further question, "which algorithm do you wish to use?" followed by codes of the various algorithms available such as (a) (c) (c) etc.

5. The operator selects an algorithm using the keyboard. Typically the general multi-variate normal (GMVN) algorithm will be assumed to be chosen although there are many others available, see the book entitled "Pattern Classification and Scene Analysis by Duda and Hart".

6. With the algorithm selected 36 generates a further request "specify parameters" and indicates the parameters by codes e.g. 1,2,3,4, etc.

7. Using keyboard 34 one or more parameters are selected, for function computers 22 and 24 to measure. Alternatively a special control (not shown) sets the instrument to automatically select those parameters best suited for the selected algorithm.

8. Depressing the continue control on keyboard 34 causes the analysis of the field to proceed and scans the field and parameter values are generated by 22 and 24, for the detected objects.

9. The parameter values of each object are stored in memory 32,

10. When all the feature parameters have been measured 28 and 36 produce an indication in the CRT adjacent the first of the detected objects in the displayed field.

11. The operator examines the indicated object (if necessary through a microscope) and indicates on 34 which of *n* classes it belongs to. The classification determines the class store in the memory 32 into which a count pulse for the object is to be inserted, together with parameter value signals. After transfer into the class store the indication moves to the next object in the field, while the operator examines and classifies using keyboard 34 as before. The parameter value signals for the secured object are routed to the appropriate class store.

12. All the remaining objects in the field are treated in the same way.

13. When all the objects have been classified 28 instructs the operator via the display to either number of objects which have to be presented to the instrument for complete training will vary from one problem to another and only experience will indicate when sufficient objects have been analysed and classified.

14. When sufficient objects (or all available objects) have been classified the keyboard "finish" control is depressed, causing 28 to extract the information in the class stores to generate a threshold criterion for classifying future objects.

In one arrangement the instrument produces accumulated arithmetic means for the parameter measurements for each of the classes which have been designated by the operator together with a co-variance matrix of the classified parameters. When the finish key is depressed, the arithmetic unit 30 in combination with the information in the stores and the control unit 28 produces the inverse co-variance matrix and the arithmetic means together with the inverse co-variance matrix are stored. The mathematical processes involved are described in chapter 3 of the book previously referred to by Duda and Hart.

Classifying mode.

The instrument is now ready to classify fields containing a similar range of objects.

1. The classify keyboard switch is depressed to set the control unit 28.

2. The text generator 36 indicates "READY" when the control unit 28 is ready after which the operator presses the "START" button.

3. This causes the field of view to be scanned an appropriate number of times so as to allow for the parameters called for by the pre-programmed information to be measured by the function computers 22, 24, etc. and the measured parameters for each detected object are stored.

4. When completed the control unit 28 inhibits function computers 22, 24, etc. and applies the information stored in the memory 32 for each object to the classification formula using the arithmetic unit 30 to calculate one or more overall parameter values for each object in turn. These are compared and depending on the value of the single overall parameter value relative to a threshold or the relative overall parameter values as compared with each other, so a final classifying signal is obtained for each object.

5. The instrument continues in this way for each detected object.

6. After classifying one field the instrument can either:-

(1) proceed to classify the next field unit until such time as all of a sequence of fields or a pre-determined number of fields have been classified, or

(2) stop the analysis at the end of the field so that the results can be checked before another field is proceeded to.

Although not described, one of the classifications conveniently comprises a "don't know" store which accumulates the number of objects which are scanned and measured but for which there is no clear classification. A check can be made either at the end of each field or periodically on the number of objects which have been so classified and/or alternatively an

alarm can be generated if the number of unknown objects exceeds a predetermined number which can either be on an accumulating basis or on the basis of the absolute number of objects per field or a percentage of the total number of objects per field.

CLAIMS

1. A method of classifying a plurality of detected features in a field of view comprising:-

(1) scanning a field containing features to be analysed to obtain a video signal relating to the features,

(2) displaying the video signal on a TV monitor,

(3) selecting a specimen feature from the display,

(4) causing the analyser to make measurements on signals obtained from the video signal to produce a value signal of a parameter of the specimen feature,

(5) the analyser generating from the value signal a classifying threshold for comparison with value signals obtained by scanning other features,

(6) performing said comparison,

((7) generating and identifying signal for each comparison for which the classifying threshold criterion is satisfied, and

(8) displaying the identification signal for each feature in the display which satisfies the said criterion to allow a visual check to be made on the accuracy of the automatic setting of the classifying threshold.

2. Apparatus for performing the method of claim 1, comprising:-

(1) means for scanning a field containing features to be analysed to obtain a video signal relating to the features,

(2) a television monitor for displaying the video signal

(3) means for selecting a specimen feature from the display and isolating electrical signal pulses relating to the feature,

(4) first circuit means for making measurements on the isolated signal to produce a value signal of a parameter of the specimen feature,

(5) second circuit means for generating from the value signal a classifying threshold for comparison with value signals obtained by scanning other features,

(6) a comparator for performing said comparison,

(7) generating circuit means for generating and identifying signals for each comparison for which the classifying threshold criterion is satisfied, and

(8) third circuit means for causing the identifying signal to be included in the television display for each feature in the display which satisfies the said criterion, to allow a visual check to be made on the accuracy of the automatic setting of the classifying threshold.

3. A method as claimed in claim 1 wherein step 8 of the method comprises the following subsidiary steps:-

(1) visually checking that each displayed identifying signal with the feature to which it relates,

(2) changing the displayed identifying signal associated with a feature which has been incorrectly classified and

(3) modifying the value of the classifying threshold so as either to include or to exclude the parameter value of the incorrectly classified feature from the computation of the classifying threshold value.

4. Apparatus for performing the method as claimed in claim 3 comprising fourth circuit means associated with the means for selecting one of the features whereby a displayed identifying signal can be isolated together with the parameter information signals relating to the feature concerned,

control means for changing the form of the signal producing the identifying signal so as to produce either no identifying signal or a different identifying signal,

fifth circuit means for inserting the changed identifying signal into the display in place of the original identifying signal and sixth circuit means for adding or substracting the parameter values relating to the incorrectly classifying feature to or from the signals used to determine the classifying threshold.

5. A method as claimed in claim 3 in which the parameter value signals for a feature identified as being incorrectly classified, together with signal information indicating the correct classification for the feature, are stored in a store, an average value for the classifying threshold is obtained by combining with (or eliminating from) the parameter values determining the classifying threshold the stored parameter values from the feature shown to be incorrectly classified, so as to obtain a new value for the classifying threshold which takes account of the additional or reduced parameter values to be used.

6. Apparatus for performing the method of claim 5 further comprising:-

(1) a signal store for storing the parameter value signals for a feature identified as being incorrectly classified together with signal information indicating the correct classification for the feature,

(2) circuit means for producing an average value of two signals applied thereto,

(3) a second store for storing the classifying threshold,

(4) means for addressing the two stores and supplying signals therefrom to the averaging circuit to produce a new classifying threshold value, and

(5) circuit means for retracing the signals in the second store with the new classifying threshold.

7. A method as claimed in claim 5 wherein the step of comparing the parameter values of a feature identified as being incorrectly classified is performed a second time after the new classifying threshold value has been computed.

8. Apparatus for performing the method of claim 7 further comprising circuit means for producing a comparison between the new classifying threshold and the parameter information relating to a feature previously identified as being incorrectly classified and producing a fresh identifying signal for the incorrectly classified feature and displaying same in the place of the previous incorrect identifying signal.

9. A method as claimed in claim 7 further

comprising the step of accumulating count pulses corresponding to the number of successes in each of the succession of fields or features to allow for the determination of the level of accuracy to which the classification procedure is being performed by the analyser.

10. Apparatus for performing the method of claim 9 further comprising circuit means for producing a count pulse for each detected feature in a field, circuit means for producing a first set of count pulses corresponding to those detected features which are classified in the first instance and for which identifying signals are produced, another circuit means for producing count pulses for each classified feature which has to be reclassified within the field, means for displaying the number of unaccurate classifications as a percentage of the total number of classifications performed and means for storing the percentage value so obtained for future reference.

11. A method of classifying a plurality of detected features in a field comprising the steps of:-

(1) scanning a field containing features from n groups,

(2) entering the information to indicate the n groups into which the features will fall if classified correctly,

(3) making measurements on signals obtained from scanning the features to produce value signals therefrom of different parameters of the features,

(4) performing a series of comparisons on the value signals using a plurality of threshold values to form n groupings of value signals,

(5) noting and storing the values of the thresholds which result in n groupings,

(6) scanning future fields containing similar features belonging to the same n groups,

(7) comparing value signals for the scanning of the subsequent fields with the stored threshold values to classify the features with subsequent fields,

(8) displaying each field whilst being scanned and,

(9) displaying identifying signals in the field display identifying the classification of the features in the display.

12. A method as claimed in claim 11 in which the series of comparisons using thresholds forming the n groupings is modified as a result of visual inspection of the identifying signals in the display to allow operator interaction, a modification being effected either by the operator directly or by the apparatus performing the analysis in response to information previously inserted by the operator.

13. Apparatus for classifying a plurality of detected features in a field of view comprising:-

(1) means for performing measurements on information arising from scanning the field containing the features so as to obtain information signals corresponding to the numerical value of a parameter of each detected feature,

(2) means for identifying selected ones of the features as falling within a class,

(3) means for deriving a classifying threshold from the information signals relating to the measured parameters of the identified features,

(4) means for storing a signal corresponding to the classifying threshold value, and

(5) means for comparing during the scanning of the field (or subsequent fields) the measured parameter values for the other features with the classifying threshold (or a signal derived therefrom) and generating identifying signals from said comparison to produce classifying indication marks in the display for indicating those features in the display which fall within each of the different classes.

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